2-MWh Flow Battery Application by PacifiCorp in Utah

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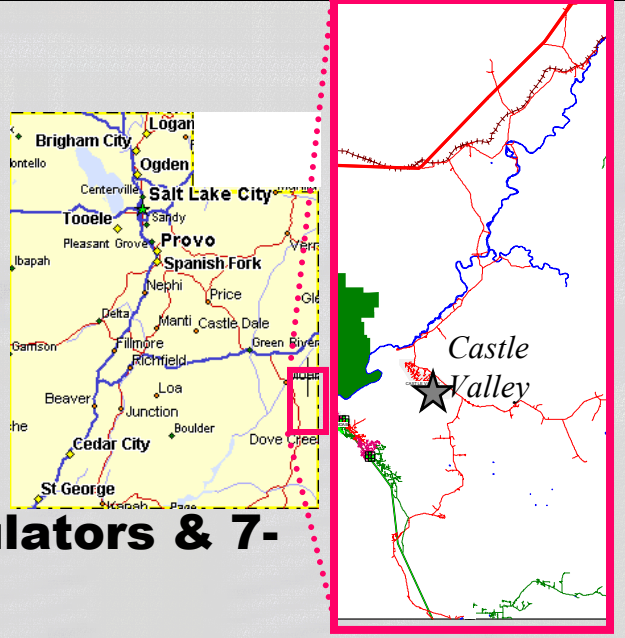
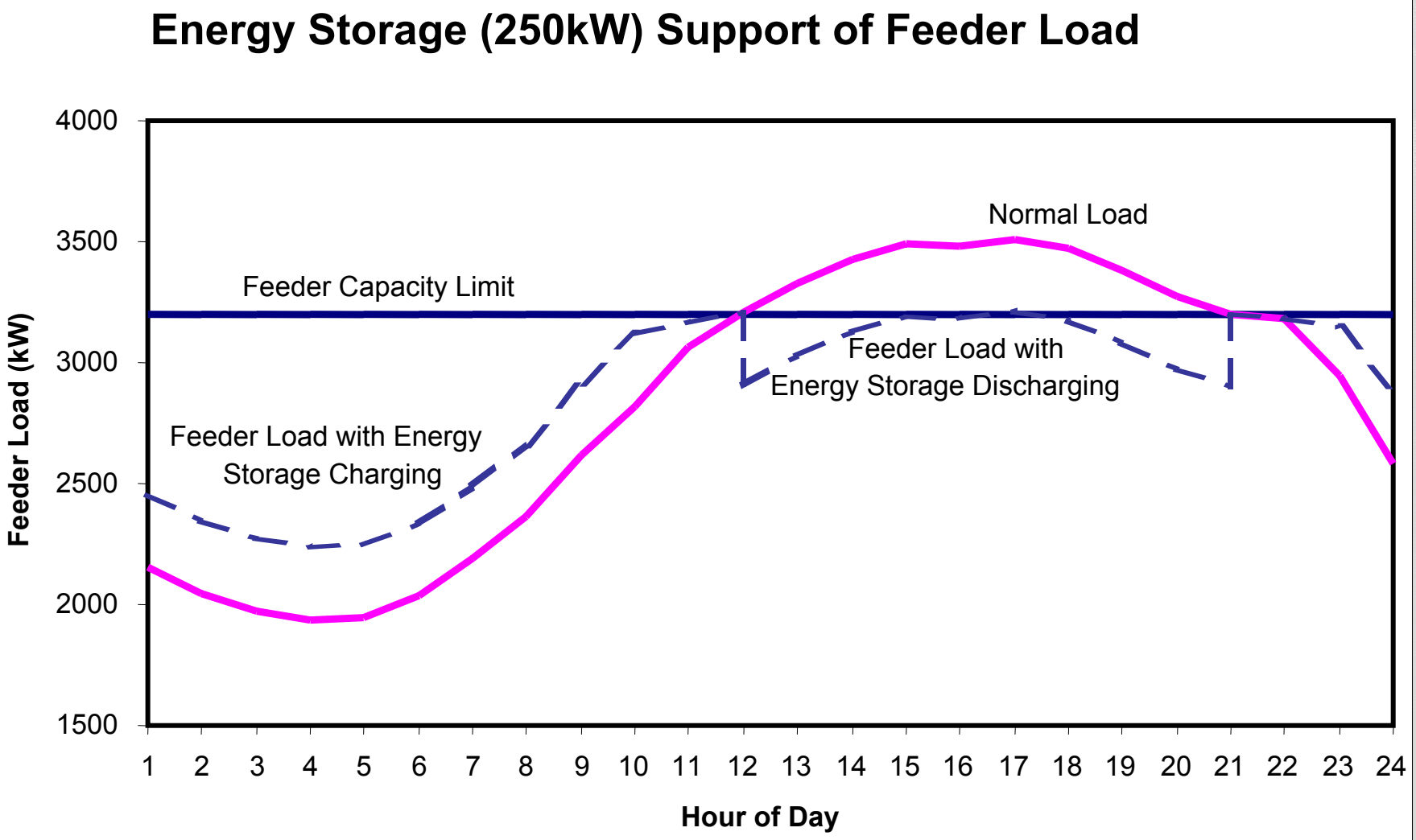
Rattlesnake#22 25kV Feeder



- Environmentally Pristine Southeast Utah
  - East of Moab
  - East of Arches National Park
  - Along Colorado River valley
- 209-mile long 25kV feeder, with 3-line regulators & 7-reclosers
- Possible denial of new connects because feeder cannot supply any significant amount of new load without causing low voltage to existing customers.
- Because feeder is so long, reliability and power quality led to Public Service Commission Complaints. PacifiCorp agreed to fix.
- Traditional alternatives to add capacity and improve service were very costly and environmentally difficult.
- Demonstrated distribution benefits of VRB energy storage as part of PacifiCorp's DG Strategy – 2 MWh, 250kW VRB-ESS (expandable to 1MW) in Castle Valley, Utah

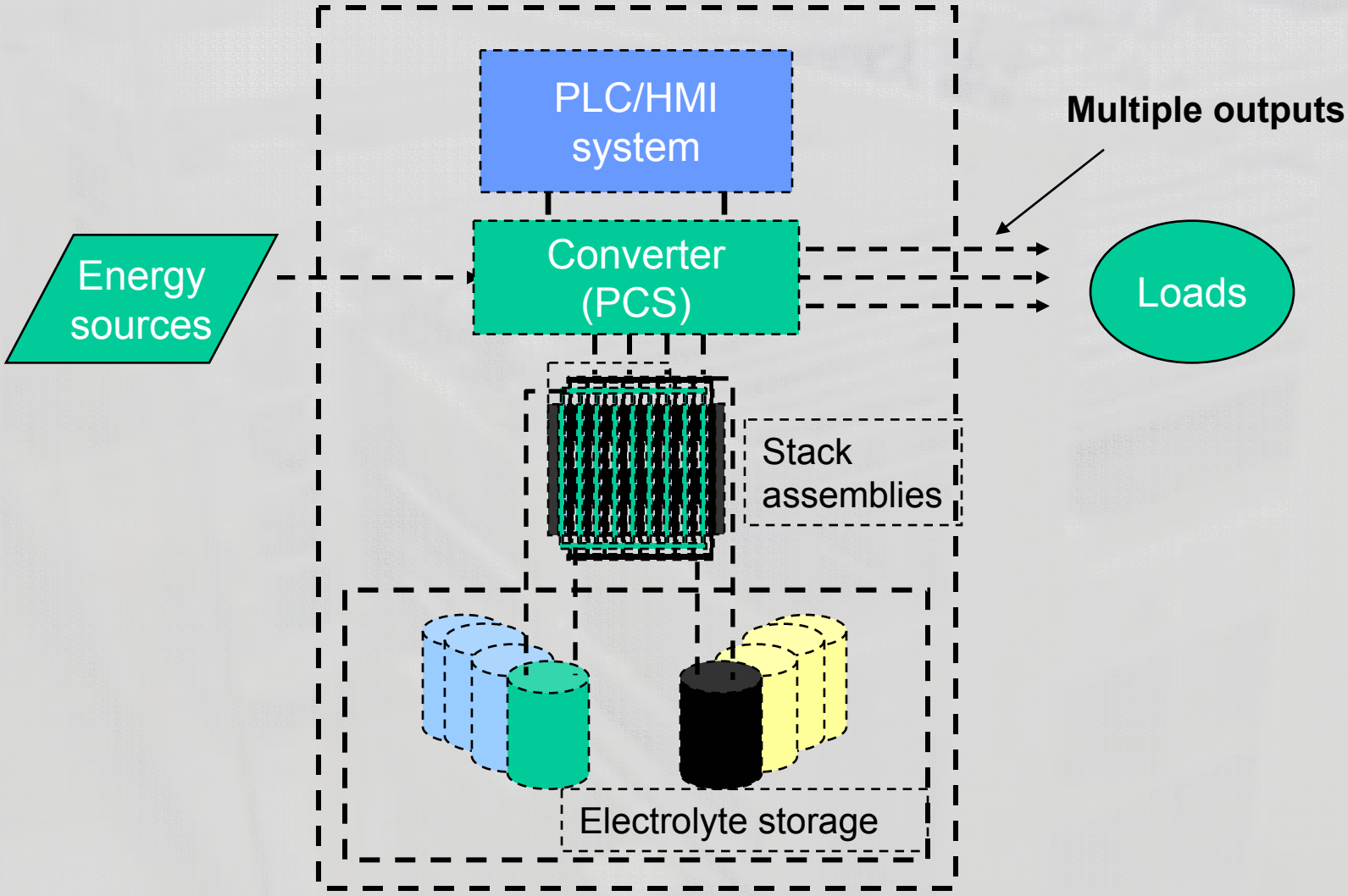
Daily Load Profile



What is a Flow Battery?

- An electrochemical *energy storage system*
- Electrolyte is stored outside the cell stack, so power and energy are independent
- Based on a reversible chemical reaction within a sealed system
- Electricity can be stored indefinitely in a liquid with very low self discharge
- Energy can be recovered almost instantaneously (< 5ms)

Flow Battery Components



Technical Advantages of Flow Batteries

- High-energy efficiencies: 70% round trip.
- Storage capacity can be easily increased by adding electrolyte.
- Designed for unattended operation with very low maintenance costs ($0.008/kWh).
- Ambient/Low operating temperature.
- Can be discharged and charged >13,000 times without performance degradation.
- Intelligent, programmable PCS provides four-quadrant control and simultaneous real and reactive energy (VARs).

Environmental Advantages

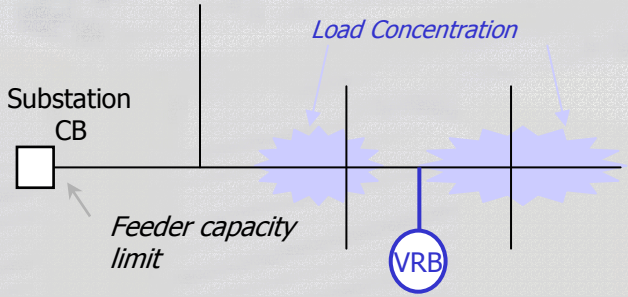
The Green Battery

- No heavy metals such as lead, nickel, zinc and cadmium
- No air emission; minimal sound emissions
- Electrolytes have indefinite life
  - No disposal issues
  - Completely reusable
- PVC piping system
- Fiberglass tanks


Vanteck

Cost Benefit Analysis

- **Alternate line and substation costs - $4million with 3 year lead times**
- **Diesel Engine – (DG) - polluting , difficult to permit, long distance from fuel supply**
- **CAPEX $500/kWh (first in USA)**
- **O&M $0.008/kWh discharged**
- **VAR support – regulation control reduces need for switched capacitors**
- **Reduces line losses by ~40 kW**
- **Charge at night, discharge on peak – arbitrage value**



Cost Benefit - Capital Deferral (continued)

- **Capital deferral - 7.5%, 10 years. Cost of upgrade $4 million**
- **Cost of VRB-ESS = $1,000,000 ($500/kWh)**
- **Arbitrage savings – 3 to 4 c/kWh = $17,280/year**
- **Net Annual savings = ($4 million - $1 million) x 7.5% plus arbitrage savings = $242,420**
- **IRR = 20% (before tax, unleveraged, 10 years)**

PacifiCorp Flow Battery Future Plans

- Advanced application development:
  - Advanced power quality applications
  - Advanced islanded operations
  - Adaptive charge/discharge energy arbitrage control algorithms
  - Advanced dynamic voltage control algorithms
  - Dynamic stability control algorithms
  - Wind farm application studies
- Increases to capacity through:
  - Additional cell stacks
  - Higher capacity inverter
  - Increased molarity of the electrolyte
- Can relocate to new site once transmission line and sub is built
- Investigating future telecom site and substation battery replacements